Session 742

Avoiding Common Mechanical Integrity Mistakes

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The following three slides from OSHA[1] illustrate results from the Refinery Special Emphasis Program inspections to date. Note that of the 215 Process Safety Management (PSM) citations listed in the first slide, 48 of them (22%) are either equipment deficiencies or other mechanical integrity issues. The second and third slides list examples of shortcomings identified in the mechanical integrity area.

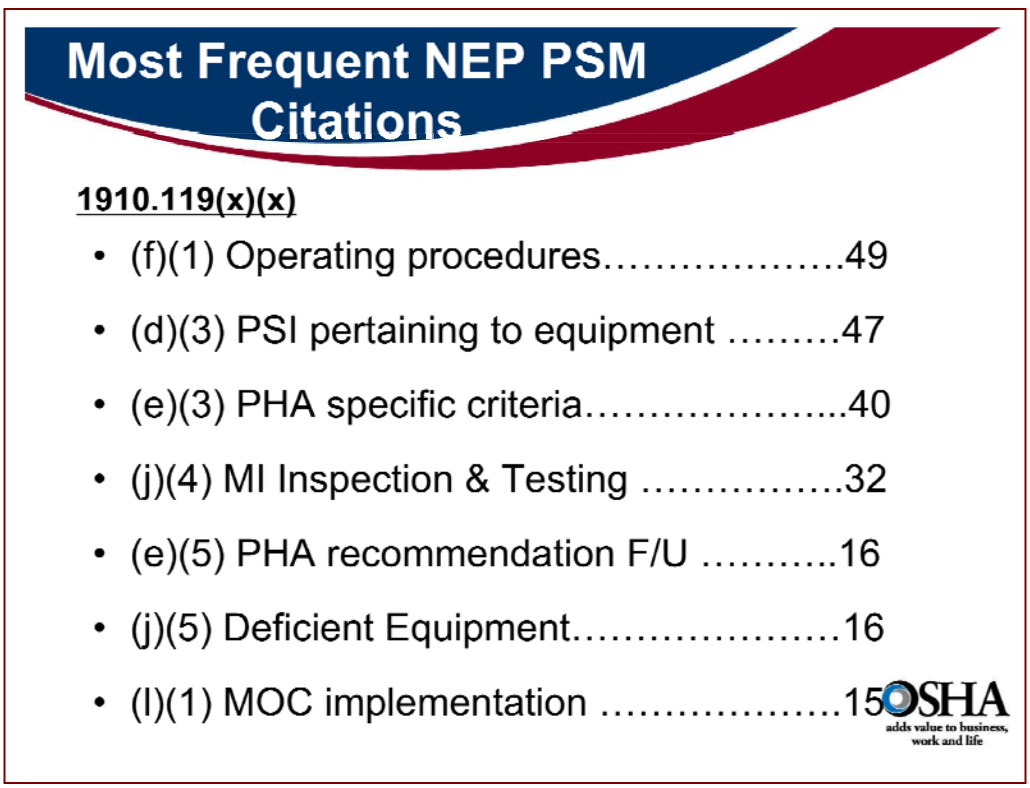

Figure 1

[1] From Mike Marshall, U.S. Department of Labor – O.S.H.A. 09/22/2008

Citation Findings

- **Equipment deficiencies not corrected**
  - Charge drum with heavy corrosion between shell and support saddles
  - Toxic and flammable detectors in control room ducting not in working order
  - Building pressurization system not working
  - Unit HF detectors not in working order
  - Failure to follow RAGAGAP for relief valves – set at 270 psi with a MAWP of 150 psi and 540 psi for MAWP of 480 psi.
  - Pump with failed primary seal in service

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Figure 2

Citation Findings

- **Did not develop Mechanical Integrity program procedure for:**
  - Inspecting pressure vessels with integrally bonded liners
  - CUI inspections of pressure vessel and piping
  - Inspecting injection points on refinery piping
  - Addressing anomalous inspection data pertaining to metal thicknesses for pressure vessels and piping
  - Addressing application of engineered clamps to pressure vessels and piping to ensure consistent administration throughout the refinery
  - Historic data was not entered into the Risk Based Mechanical Inspection program nor the MI inspection data software until 2007
  - Inspecting pressure vessels with non-metallic linings

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Figure 3

The following Mechanical Integrity shortcomings are typical of those found in third-party PSM audits:

- ***Failure to identify PSM-covered equipment***

  Some facilities take the attitude that "anything in the fence line we consider a part of PSM." The problem with this is that once such a policy is formally stated, regulatory inspectors must take the policy at face value. That means that non-process equipment, which has no potential to cause or contribute to an uncontrolled release of hazardous chemicals, must be treated the same as equipment that can cause such a release. This can lead to absurdities such as an inspector asking to see the Process Hazards Analysis (PHA) on systems with no process hazards.

  To reduce the amount of paperwork required, most owners use a consistent philosophy in determining what equipment belongs in their PSM program and what doesn't. One typical means of identifying PSM-covered equipment is the "two valve rule," which states that any piping that is physically connected to the hazardous chemical process remains a part of the PSM-covered equipment until isolated by two manual block valves.

  The PSM-covered equipment should be clearly identified and segregated from non-PSM-covered equipment. The usual way of designating this is to use a set of Piping and Instrument diagrams (P&IDs) with the PSM-covered equipment highlighted. Additionally, a written record of what method was used to identify the equipment (two-valve rule or other) should be a part of the site Process Safety Information (PSI).

- ***Failure to consider the carseal program as part of PSM***

  Safety-critical equipment such as pressure relief valves, rupture discs, vent headers, and flare headers will not function if isolated by manual block valves. To ensure safe operation, most such equipment's manual block valves are either chained/locked and/or carsealed in their operational positions.

  To be effective, a carseal program must be regularly verified, documented, and audited. Any carseal found broken, or any safety-critical manual valve found in an improper position should be treated as a PSM-Near-Miss. A full PSM investigation should be held to determine what happened, why it happened, and what should be done to prevent it from happening again.

  Carseal programs that are not given this level of attention are usually not effective.

- ***Failure to perform mechanical integrity inspections on schedule***

  Audits usually reveal some overdue percentage of pressure vessel, tank, instrument, and rotating equipment inspections. When an inspection must be delayed, a Management of Change (MOC) procedure should be instigated to determine what, if any, additional safeguards are required in the interval between the original inspection due date and the time of the delayed inspection.

  If overdue inspections are a continuing problem, a formal root cause analysis should be performed to determine why. Additional resources may be required to catch up on the inspection program. In some cases, a risk analysis can be used to determine which, if any, inspections can be modified (via MOC) to safely increase the inspection intervals.

Typical inspection frequencies are:

Equipment	Applicable Code/Std./Industry Guidance	DOCUMENTED Inspection Interval
Chainfalls, Hoists, Slings, Monorails & Overhead Cranes	CCPS – Plant Guidelines for Technical Management of Chemical Process Safety, Appendix 8B	Visual inspection every six months
Compressors	Manufacturer's Recommendations	Typically, annual overspeed trip and continuous or periodic vibration monitoring
Critical Electrical Distribution Equipment	CCPS – Plant Guidelines for Technical Management of Chemical Process Safety, Appendix 8B	Per Manufacturer's recommendations or internal history
Fire Protection Equipment	NFPA Codes (various), API 2001 Fire Protection in Refineries, UL Standards, Insurance company requirements	Daily – Mobile fire equipment visual only, heater visual check (cold weather only) Weekly – Portable fire extinguishers visual only Monthly – Sprinkler, alarm, foam, & deluge systems visual only, riser flow test, heating systems test (cold weather only) Annually – Fire water headers & pumps flow testing, fire hoses pressure testing, foam chemical analysis
Chemical Hoses	CCPS – Plant Guidelines for Technical Management of Chemical Process Safety, Appendix 8B	Every 6 months visual inspection
Critical Instruments	ISA-S84.01 Application of Safety Instrumented Systems to the Process Industries	Frequency based on criticality & field reliability
Storage tanks high level alarm instruments	API RP 2350	Annual test using manufacturer's test procedure
Critical oxygen and continuous process analyzers	API 550, Part II, Section 5	Frequency based on criticality & manufacturer recommendation
Hazardous chemical process piping	ANSI B31.3 API RP 574, Section 5.1 API 570, Section 4	Class 1 (high-hazard) 5 years (visual & thickness) Class 2 - 5 years visual and 10 years thickness Class 3 – 10 years (visual & thickness) Injection Points – 3 years (thickness) visual by class Soil/Air interfaces – visual & thickness by class
Chlorine piping	Chlorine Institute Pamphlet 60	Annual comprehensive Semiannual visual Bimonthly preventative maintenance
Flex hoses & expansion joints	CCPS – Plant Guidelines for Technical Management of Chemical Process Safety, Appendix 8B	Annual external inspection
Pumps	CCPS – Plant Guidelines for Technical Management of Chemical Process Safety, Appendix 8B	Periodic visual inspection & vibration monitoring per manufacturer's recommendations
Spring-loaded relief valves	ASME Boiler & Pressure Vessel Code, Section 8 – Pressure Vessels	Monthly – Block valve position and seat leakage Annually – Any dirty or corrosive gas service, any liquid service protected by rupture disc with knife blade, any hazardous liquid service 2 years – any water & steam service, clean liquid service, moderately clean gas service 3 years – Any clean, dry, and noncorrosive gas service 3-5 years – Any liquid service protected by rupture disc without knife blade

Equipment	Applicable Code/Std./Industry Guidance	**<u>DOCUMENTED</u>** Inspection Interval
Pilot-operated relief valves	ASME Boiler & Pressure Vessel Code, Section 8 – Pressure Vessels	Monthly – Block valve position & seat leakage Annually – Hazardous chemicals, moderately clean gas service 2 years – Clean, dry, & noncorrosive gas service, nonresidue/clean chemicals
Boiler relief valves	ASME Boiler & Pressure Vessel Code, Section 1 – Power Boilers National Boiler Inspection Code, ANSI/NB 23 Appendix A, A-300	Low-Pressure heating boilers & Power boilers ≤ 400 psig – manual test monthly, pressure test annually Power boilers > 400 psig – Per operating history
Chlorine relief valves (nonrefrigerated chlorine storage)	ASME Boiler & Pressure Vessel Code, Section 8 – Pressure Vessels, Chlorine Institute Pamphlet 5	Biannual or annual inspection based on field history
Ammonia relief valves	ASME Boiler & Pressure Vessel Code, Section 8, ANSI K61.1	Annual external inspection 5 years refurbish or replace
Storage tanks (atmospheric)	API 620, API 650, UL 142	External – every 5 years or at ¼ of remaining corrosion-rate life, whichever is less Internal – Every 10 years if corrosion history is not available, Every 20 years or based on corrosion rates if trending is available
Manual chlorine block valves (non-refrigerated svc.)	Chlorine Institute Pamphlet 5	Every 2 years
Safety-critical manual block valves	Recognized & Accepted Good Engineering Practice	Every 3 years bench test or replace (based on field service)
Pressure Vessels	ASME Boiler & Pressure Vessel Code, Section 8, API RP 572, ANSI/NB-23, API 510	External – Every 5 years or at ¼ of remaining corrosion-rate life, whichever is less Internal – Every 10 years or at ½ of remaining corrosion-rate life, whichever is less
Boilers	ASME Boiler & Pressure Vessel Code, Section 1 – Power Boilers National Boiler Inspection Code ANSI/NB 23	Typically every 3-5 years (internal) as set by local jurisdictions
Steam Deaerators	ASME Boiler & Pressure Vessel Code, Section 8 – Pressure Vessels	Every 3 years - Internal visual inspection and wet fluorescent particle testing (may substitute radiographic or ultrasound)

- ***Failure to identify critical instruments***

  In many PSM-covered processes, no risk-based analysis of critical instruments has ever been performed. The problem with not doing such an evaluation is that the instrument department can easily be overwhelmed with work if all instruments require the same calibration frequency. In such situations, critical instruments often go without attention until it becomes apparent that they are not working.

  If instruments are ranked by the risk posed if they fail to function, then maintenance and calibration can be performed at increased frequency on the most important instruments. This is a more intelligent use of available resources.

- ***Failure to re-evaluate safety systems after debottlenecking***

  Often, process systems were modified for higher throughput or "debottlenecked" after their initial construction but before 1992 (when the PSM standard and its MOC requirements became law). In such situations, the original relief devices and trip systems are often still in use. If these relief devices and trip systems have not been recalculated for the newer pressure, flow, and temperature requirements, they may not be sufficient to provide safety when needed.

  During audits, safety-critical equipment should be reviewed to make sure that equipment calculations accurately reflect the current operating conditions.

- ***Failure to identify safety-critical manual block valves***

  Manual block valves are expected to be gas or liquid-tight when closed. All block valves, however, eventually corrode, erode, or wear with age. When worn, manual block valves can leak through.

  Leak-through can sometimes result in catastrophic consequences. Despite this, few companies have done an analysis to identify their safety-critical manual block valves. Even fewer companies have a periodic replacement or inspection program for such manual valves.

  Failure of manual block valves has resulted in major explosions elsewhere in industry.[2] A safety-critical manual block valve identification and maintenance/replacement program should now be mandatory.

[2] Chemical Safety Board Incident Investigation NO. 2003-01-I-MS

- ***Failure to verify quality control on incoming spares***

  Manufacturers can change product specifications without notice. Neither the manufacturer nor the distributor is legally obligated to notify the end user of changes in performance, materials of construction, or reliability.

  Many MI programs fail to specify who is responsible for quality control on incoming warehouse spares. The responsibility is often left to the "qualified vendor," but no audits are done to verify that the vendor is actually doing what is expected.

  Not only piping metallurgy, but also instrumentation, rupture discs, rotating equipment, and the remainder of safety-critical warehouse spares must be held to quality standards. Someone must be designated to be responsible for verification. The process must be audited on a periodic basis to ensure that the system is working.

- ***Failure to segregate rupture discs and safety valves in the warehouse***

  If rupture discs or relief valves of the same physical size but different pressure settings are in adjacent warehouse bins, they can easily be intermixed. To avoid confusion, segregate similarly sized, but differently pressure-rated parts to non-adjacent areas of the warehouse. Clear labeling also helps prevent confusion.

- ***Failure to segregate alloy materials in the warehouse***

  When alloy parts of different composition are in proximity, or when carbon-steel parts are in proximity to similar alloy parts, confusion is possible. One refinery's coker outlet failed because a carbon steel outlet pipe was inadvertently substituted for a high-temperature alloy pipe. The resulting fire caused an extended production outage.[3]

  Segregate alloy parts from each other and from similar carbon steel parts. Having parts in different areas of the warehouse along with a clear labeling system can avoid confusion.

- ***Failure to have a usable warehouse inventory system***

  Often, the warehouse inventory system is a "legacy" system that has been around for decades, and whose software is understood by only the few who have to use the system on a daily basis. If the warehouse inventory system is excessively complex, personnel tend to make their own "warehouse maps" that reside in personal lockers.

  The problem with such a "warehouse map" system is that when the warehouse personnel opt to move materials, the maintenance and operations personnel who must use the warehouse (often after normal business hours) don't get the word. This can lead to mistakes being made in selection of plant spares with sometimes-catastrophic consequences.

  The warehouse inventory system must be user-friendly, understood by all personnel who are expected to use it, and available at all hours. Readily available

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[3] Exxon Refinery, Baton Rouge, LA

documentation on how to use the warehouse inventory system must exist. Documentation must be written at the level of those expected to use the documentation.

- ***Failure to train personnel on the warehouse inventory system***

  Even if a usable warehouse inventory system exists, in many cases the instructions on how to use the system are passed on verbally. This means that over time, inaccuracies abound that may lead to improper parts selection.

  All mechanics, operators, and shift foremen who are expected to use the inventory system should receive formal, periodic, and standardized training. The training should cover all aspects of using the inventory system to find parts, and if necessary, to order parts. The training should be documented in writing, and the trained users should have to periodically demonstrate their competency in using the inventory system.

  Should changes occur in the software or the physical layout of the warehouse, all users should receive update training and be required to demonstrate their understanding of the training received. Warehouse software and physical layout changes should be tracked via MOC.

- ***Failure to implement additional safeguards when running with equipment deficiencies***

  When inspections identify equipment deficiencies, and immediate repair or replacement is not possible, consideration should be given to the prudence of additional safeguards. The safeguards should be sufficient to ensure safe operation between the time that a deficiency is identified and the time that the deficiency can be eliminated. Such safeguards may include reductions in flow, temperature, or pressure until the equipment is repaired. Any such considerations should be documented via MOC.

Additionally, the following list of reports from the Chemical Safety Board illustrates a variety of mechanical integrity issues that contributed to or resulted in catastrophic explosions, fires, and/or chemical releases.

Chemical Safety Board Investigations				
What	Where	When	MI Issues	CSB No.
Barton Solvents ethyl acetate tote-tank explosion	Des Moines, IA	10/29/2K7	No grounding-bonding procedure	No. 2008-02-I-IA
Bethlehem Steel fire & explosion	Chesterton, IN	2/2/2K1	Failure to remove dead legs from piping	NO. 2001-02-I-IN
BP Polymers Thermal Decomposition	Augusta, GA	3/13/2K1	Design did not anticipate pluggage from polymerization	NO. 2001-03-I-GA
Catalyst Systems, Inc. Benzoyl Peroxide Explosion & Fire	Gnadenhutten, OH	1/2/2K3	Bad temperature probe led to runaway reaction.	NO. 2003-03-C-OH
Sonat Exploration Co. Explosion & Fire	Pitkin, LA	3/4/1998	Overpressured atmospheric tank failed – no PSVs, No vent	No. 1998-002-I-LA

Chemical Safety Board Investigations				
What	Where	When	MI Issues	CSB No.
Concept Sciences Hydroxylamine Explosion	Hanover Township, PA	2/19/1999	Insufficient controls allowed runaway decomposition	No. 1999-13-C-PA
ASCO acetylene explosion & fire	Perth Amboy, NJ	1/25/2K5	Bad check valve allowed acetylene to flow through an open drain valve into an enclosed space	No. 2005-03-B
D.D. Williamson & Co. aqua-ammonia Explosion & Fire	Louisville, KY	4/11/2K3	Overheated tank with no relief device	No. 2003-11-I-KY
Barton Solvents naphtha tank explosion	Wichita, KS	7/17/2K7	Level float not grounded/bonded	No. 2007-06-I-KS
Technic, Inc. vent header explosion	Cranston, RI	2/7/2K3	Unstable, shock-sensitive accumulations in vent line not recognized in design	NO. 2003-08-I-RI
West Pharmaceutical polyethylene Dust Explosion	Kinston, NC	1/29/2K3	System not designed to contain fugitive dusts	NO. 2003-07-I-NC
Bethune Point wastewater methanol tank explosion	Daytona Beach, FL	1/11/2K6	Flame arrestor not maintained	NO. 2006-03-I-FL
BP explosion	Texas City, TX	3/23/2K5	Instruments not maintained	NO. 2005-04-I-TX
CAI Inc. vapor cloud explosion	Danvers, MA	11/22/2K6	Defective heater vaporized solvents, tank vented inside building	NO. 2007-03-I-MA
CTA Acoustics phenolic resin dust explosion	Corbin, KY	2/20/2K3	Fugitive dust in enclosed building	NO. 2003-09-I-KY
DPC Enterprises chlorine release	Glendale, AZ	11/17/2K3	Lack of controls on chlorination	NO.2004-02-I-AZ
MFG Chemical triallyl cyanurate (TAC) allyl chloride vapor release	Dalton, GA	5/12/2K4	Runaway reaction caused reactor failure – inadequate cooling & vessel inadequate	NO. 2004-09-I-GA
Valero-McKee refinery LPG fire	Sunray, TX	2/16/2K7	Frozen dead leg failed, support steel not fireproofed	NO. 2007-05-I-TX
Honeywell chlorine release	Baton Rouge, LA	7/20/2K3	Exchanger failure, insufficient remote emergency shutoff switches	NO. 2003-13-I-LA
Marcus Oil polyethylene wax explosion	Houston, TX	12/4/2K4	Non-code repair of pressure vessel, no relief devices	No. 2005-02-I-TX
Praxair gas cylinder fire	St. Louis, MO	6/24/2K5	No fire barriers or LEL detectors	No. 2005-05-B
Sterigenics ethylene oxide explosion	Ontario, CA	8/19/2K4	Auto-purge system overridden and vessel opened	NO. 2004-11-I-CA
Universal Form Clamp heptane/mineral spirits tank fire	Bellwood, IL	6/14/2K6	Malfunctioning temperature controller, no ventilation system	No. 2006-08-I-IL
DPC Enterprises chlorine release	Festus, MO	8/14/2K2	Unloading hose (of wrong material) failed	2002-04-I-MO
Motiva Refinery tank explosion	Delaware City, DE	7/17/2K1	Vapor space of sulfuric acid tanks ignited from welding slag, tanks had holes in roof & inadequate inert purge	No. 2001-05-I-DE
Environmental Enterprises, Inc. H_2S release	Cincinnati, OH	12/11/2K2	Area detector not working	NO. 2003-02-C-OH
Environmental Quality Co. hazardous waste fire	Apex, NC	10/5/2K6	No fire control detectors or control equipment	No. 2007-01-I-NC
Formosa Plastics VCM Explosion	Illiopolis, IL	4/23/2K4	Override of automatic controls	NO. 2004-10-I-IL
Herring Bros. Propane tank BLEVE	Albert City, IA	4/9/1998	Outlet piping not protected from vehicle strike, footer valve failed to function (outlet line diameter too small to trigger valve)	No. 98-007-I-IA
Sierra Explosives fire &	Mustang, NE	1/7/1998	Mixer was started with blade in solidified	NO. 98-001-I-NV

Chemical Safety Board Investigations				
What	Where	When	MI Issues	CSB No.
explosion			TNT.	
First Chemical runaway MNT reaction	Pascagoula, MS	10/13/2K2	No safety-critical manual block valve program, inadequate relief system	NO. 2003-01-I-MS
Formosa Plastics olefins vapor cloud explosion	Point Comfort, TX	10/6/2K5	Propylene piping not protected from vehicle strike, no remote isolation available	2006-01-I-TX
Georgia-Pacific H_2S release	Pennington, AL	1/16/2K2	No monitoring systems, sewers not sealed	NO. 2002-01-I-AL
Hayes-Lemmerz aluminum dust explosion	Huntington, IN	10/29/2K3	Dust collector not properly designed	NO. 2004-01-I-IN
Isotec liquid nitric oxide release	Miami Township, OH	9/21/2K3	Corrosion cracking in reactor	N. 2003-15-C-OH
Morton dye fire & explosion	Patterson, NJ	4/8/1998	Runaway reaction over pressured reactor, inadequate relief, inadequate pressure design	No. 1998-06-I-NJ
Synthron vapor cloud explosion	Morganton, NC	1/31/2K6	Runaway reaction, inadequate cooling, not all manway bolts used, failure to evaluate condenser fouling	No. 2006-04-I-NC
Third Coast Industries oil-blending plant fire	Friendswood, TX	4/1/2K2	Inadequate fire detection & control systems, buildings not designed to minimize spread of fire,	NO. 2002-03-I-TX
Tosco Avon refinery fire	Martinez, CA	2/23/1999	Piping failure released naphtha, inadequate isolation available, manual valves leaked through, pneumatic valves leaked through	NO. 99-014-I-CA